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Hiding in plain sight on Gunung Muria: A new species and first record of rock gecko (*Cnemaspis* Strauch, 1887; Squamata, Gekkonidae) from Java, Indonesia

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Abstract

We describe a new species of rock gecko of the genus *Cnemaspis* from Java, Indonesia, representing the first record of the genus for this Island. The new species was collected from the southern slopes of Gunung Muria, a dormant volcano in Central Java. The new species is easily distinguished from all congeners by having a maximum SVL of 58.1 mm in males and 56.9 mm in females; a pair of sharp conical tubercle clusters on the occiput; a warty bridge on the nuchal loop, extending from the upper tympanum and curving to the nape; dorsal tubercles not linearly arranged; 18–20 paravertebral tubercles; postmentals separated by one scale; gular, pectoral and abdominal scales, ventral scales of fore- and hindlimbs, and subcaudal scales keeled; no tubercles on lower flank; precloacal and femoral pores absent; enlarged submetacarpal scales present on the first digit of the manus; 38–40 ventral scales; 31–35 lamellae under fourth toe; two postcloacal tubercles on each side; enlarged median subcaudal scales row present; caudal tubercles encircling tail; and a sexually dimorphic ventral color pattern, with males having a yellow belly and females white and the ventral surface of the tail in males yellow proximally changing to white at mid-length, whereas in females, alternating black and white rings completely encircle the tail, which is black distally.

Key words: Central Java, *Cnemaspis,* first record, Mount Muria, new species

Abstrak

Kami mempertelakan spesies baru cicak batu dari genus *Cnemaspis* dari Jawa, Indonesia, yang juga sebagai catatan pertama genus di pulau ini. Spesies baru dikoleksi dari lereng selatan Gunung Muria, yang merupakan gunung api dorman yang berada di Jawa Tengah. Spesies baru ini mudah dibedakan dari semua kerabatnya dengan memiliki SVL maksimum 58,1 mm pada jantan dan 56,9 mm pada betina; sepasang struktur tuberkular seperti kerucut pada kepala bagian belakang; alur berkutil pada *nuchal loop*, membentang dari atas tympanum melengkung ke tengkuk; tuberkular dorsal tidak tersusun secara linier; 18–20 baris tuberkular sepanjang paravertebral; postmental dipisahkan oleh satu sisisk; gular, pektoral, abdominal, sisi ventral kaki depan dan belakang, serta sisik subcaudal berlunas; tidak ada tuberkul di lipatan paha; tidak mempunyai pori-pori prakloakal maupun femoral; pada jari pertama tungkai depan terdapat struktur submetakarpal yang membesar; pada jari pertama tungkai belakang terdapat sisik submetatarsal yang membesar; 38–40 sisik perut; 31–35 lamella di bawah jari keempat tungkai belakang; pada kanan kiri kloaka terdapat masing dua struktur tuberkular; terdapat satu baris sisik subcaudal yang membesar ditengah ventral ekor; tuberkular membentuk formasi cincin di sepanjang ekor; dan terdapat dimorfisme seksual warna pada ventral tubuh yaitu pada jantan perut dan pangkal ekor berwarna kuning dengan setengah panjang ekor hingga ujung berwarna putih, sedangkan pada betina perut berwarna putih dan ekor dengan pola cincin hitam putih yang berselang-seling dengan ujung berwarna hitam.

Kata kunci: Jawa Tengah, *Cnemaspis*, catatan pertama, Gunung Muria, spesies baru

Introduction

The African-Asian rock geckos of the genus *Cnemaspis* Strauch, 1887 comprise about 133 species (Uetz *et al.* 2018). In Southeast Asia, with 50 species, this genus is distributed in central and southern Vietnam, marginal areas of the

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Gulf of Thailand, through the Malay Peninsula, Seribuat Island, the Riau Archipelago (Anambas, Natuna, Tembelan and Belitung islands), Borneo (including the Karimata Islands), and Sumatra (including the Mentawai archipelago: Simeleu, Nias, Siberut, Pagai and Enggano islands) (Gray, 1845; Smith, 1925; Das & Bauer, 1998; Das, 2005; Grismer & Chan 2009; Grismer *et al.* 2014; Amarasinghe *et al.* 2015; Iskandar *et al*. 2017; Riyanto *et al.* 2017; Kurita *et al.* 2017). In the Greater Sundas, in Sumatra and the Riau and Mentawai archipelagoes at least 13 species have been encountered: *Cnemaspis aceh* Iskandar, Amarasinghe & McGuire, 2016; *C. andalas* Iskandar, Amarasinghe & McGuire, 2016; *C. dezwaan*i Das, 2005; *C. jacobsoni* Das, 2005; *C. minang* Iskandar, Amarasinghe & McGuire, 2016; *C. modiglianii* Das, 2005; *C. mumpuniae* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014; *C. pagai* Iskandar, Amarasinghe & McGuire, 2016; *C. purnamai* Riyanto, Hamidy, Sidik & Gunalen, 2017; *C. rajabasa* Amarasinghe, Harvey, Riyanto & Smith, 2015; *C. sundainsula* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014; *C. tapanuli* Iskandar, Amarasinghe & McGuire, 2016; and *C. whittenorum* Das, 2005; and five species are known to occur on Borneo: *C. dringi* Das & Bauer, 1998; *C. kendallii* (Gray, 1845); *C. leucura* Kurita, Nishikawa, Matsui & Hikida, 2017; *C. nigridia* (Smith, 1925); and *C. paripari* Grismer & Chan, 2009. Until now there were no records of this genus from Java. Field surveys in July and August 2018 revealed nine specimens of the genus *Cnemaspis* from Gunung Muria, Central Java, Indonesia. These represent a population sufficiently different from all currently recognized species of *Cnemaspis,* on the basis of color pattern, size, and scalation, to warrant description as a new species.

Material and methods

Specimen collection. A herpetofaunal field survey was conducted in early July 2018 by one of the authors (AISM) in Gunung Muria, Kudus Regency, Central Java, during which seven specimens of rock geckos, genus *Cnemaspis,* were obtained. Twenty-five days later, AR and MM, collected two more specimens at the same location. The specimens were captured by hand, euthanized with 20% benzocaine diluted in 70% ethanol. Liver tissue was removed for DNA extraction and stored in 95% ethanol. Voucher specimens were fixed with 10% buffered formalin, and later stored in 70% ethanol. Latitude, longitude, and elevation of the collecting localities were recorded on the WGS 84 map datum system using Garmin GPSmap 60CSx. All type specimens were deposited at the Museum Zoologicum Bogoriense (MZB), Indonesian Institute of Sciences (LIPI), Cibinong, Indonesia.

Morphological analysis. Most morphological characters, external measurements and scalation counts followed Grismer *et al.* (2014). Measurements were taken using dial calipers (Mitutoyo) to the nearest 0.1 mm, under a dissecting microscope (AmScope) on the right side. Measurements: snout–vent length (SVL, from tip of snout to anterior margin of vent); tail length (TailL, from vent to tip of tail); head length (HeadL, from posterior edge of retroarticular process of lower jaw to tip of snout); head width (HeadW, measured in a straight line at angle of jaws); head depth (HeadD, maximum height of head from occiput to throat); snout length (SnoutL, from anterior most edge of orbit to tip of snout); eye to ear distance (EED, from posterior edge of orbit to anterior edge of ear opening); ear length (EarL, maximum length of ear opening); orbital diameter (OD, horizontal diameter of eye ball); axilla–groin length (AGL, from posterior margin of forelimb, at insertion point on body, to anterior margin of hind limb, at insertion point on body). We also measured some characters on the ventral surface: antebrachium length (AntBraL, from posterior margin of elbow, while flexed, to inflection of flexed wrist); brachium length (BracL, from axilla to inflection of flexed elbow); thigh length (ThighL, from anterior margin of hind limb, at insertion on body, to knee, while flexed); and tibia length (TibiaL, from posterior surface of knee, while flexed 90º, to base of heel).

Meristic data collected were: supralabial (SupL) and infralabial (InfL) scales (counted from below the middle of the orbit to the rostral and mental scales, respectively); number of paravertebral tubercles (PVT, counted between limb insertions, in a straight line immediately right of the vertebral column); and number of subdigital lamellae under fourth toe (counted from base of first phalanx to distalmost lamella, excluding claw sheath). We noted the texture of scales (smooth, unicarinate or tricarinate) on the gular, pectoral, and abdominal regions on the ventral side of the fore- and hindlimbs and on subcaudal surfaces. The presence of tubercles along the ventral edge of the body (flank) between limb insertions, and in whorls encircling the tail was noted as were enlarged submetacarpals and submetatarsals on the first finger and toe, respectively. The presence of enlarged unpaired median subcaudals was also noted. Following Harvey *et al.* (2015) we applied methylene blue in 70% ethanol to stain specimens and better visualize some minute structures, such as subdigital keels and pores.

Color notes were taken based on digital images obtained from living specimens prior to preservation.

We also obtained character and distribution information for other Southeast Asian *Cnemaspis* species from Grismer *et al.* (2014), Amarasinghe *et al.* (2015), Iskandar *et al.* (2017), Kurita *et al.* (2017) and Riyanto *et al.* (2017).

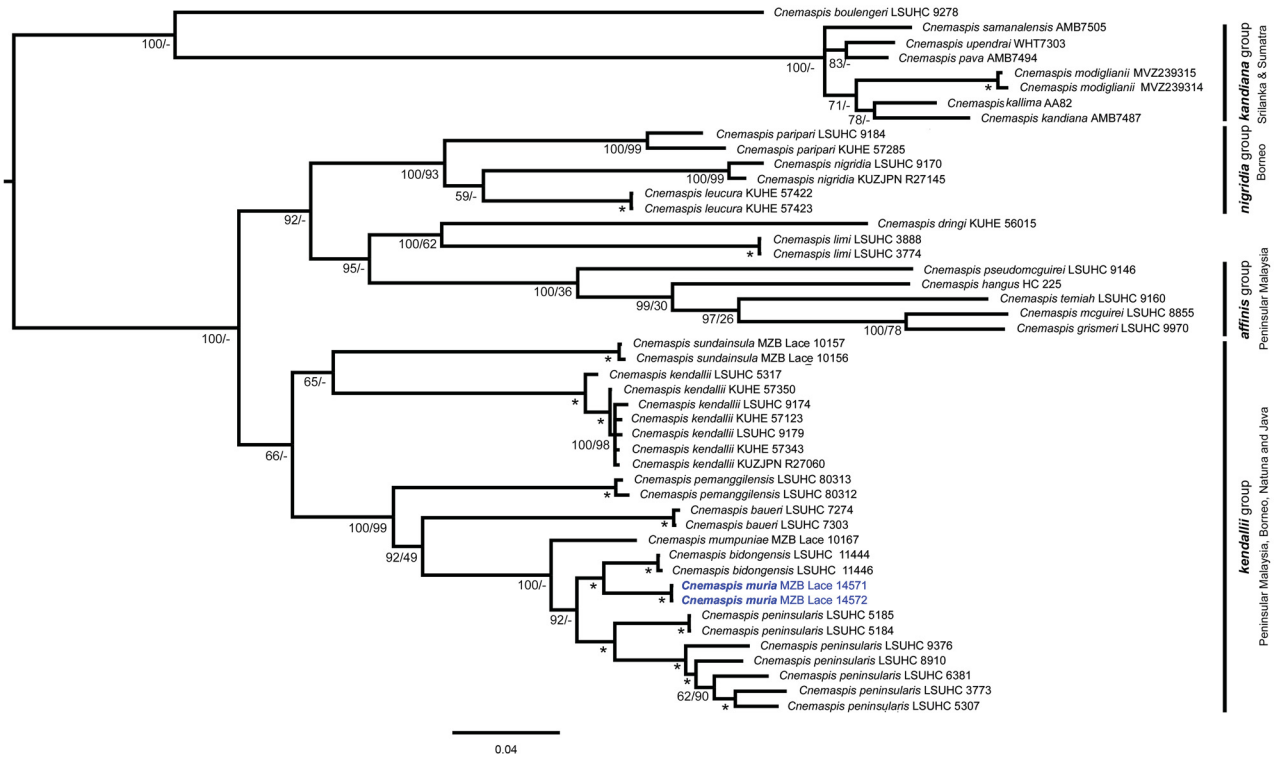

FIGURE 1. Bayesian Inference tree based upon ~954 bp NADH dehydrogenase 2 gene sequences for representative *Cnemaspis* species. Values above or below branches indicate Bayesian Posterior Probability (BPP) and Maximum Likelihood Bootsrap Proportion (MLBP), asteric indicates strongly supported clade (BPP=100 and MLBP=100).

Phylogenetic analysis. We extracted genomic DNA from liver stored in 95% using standard *phenol-chloroform* method (Sambrook *et al.* 1989). DNA amplification of the NADH dehydrogenase 2 (ND2) and partial flaking tRNAs were carried out in Polymerase Chain Reactions (PCR) using the primers M112F (5-AAGCTTTC-GGGGCCCATACC-3) and M1123R (5-GCTTAATTAAAGTGTYTGAGTTGC-3) designed in the flanking methionine and alanine tRNAs (Oliver *et al.* 20016). The PCRs were performed in 25 µl total volumes using Top Taq™ by Qiagen comprising 1.0 µl DNA template, 2.5 µl 10x Top Taq PCR buffer™, 0.5 µl 10 mM dNTP mix, 2.5 µl 10x CoralLoad, 5 µl 5x Q solution, 1.0 µl light strand primer, 1.0 µl heavy strand primer, 0.125 µl Top Taq DNA polymerase with appropriate buffer and ddH_2O to volume. PCR reactions were executed on an Eppendorf Mastercycler under following conditions: initial denaturation at 94°C for 9 min, followed by a second denaturation at 94°C for 45 s, anneling at 60°C for 45 s, followed by a cycle extension at 72°C for 1 min, for 35 cycles. The purified PCR products were sequenced directly by 1st Base Asia facility (Singapore). Sequence data were validated using Chromas pro software (Technelysium Pty Ltd, Australia) and aligned with published data from GenBank (Table 1) using Clustal W in MEGA 6.06 (Tamura *et al*. 2013). Phylogenetic analyses of 954 base pairs (bp) of ND2 and its flankig tRNAs were performed using Maximum Likelihood (ML) and Bayesian Inference (BI). We used the Akaike criterion as implemented in Kakusan 3 (Tanabe 2007) to select the best model of evolution for both BI and ML analyses. We conducted our BI analysis using MrBayess 3.2.6 (Ronquist & Huelsenbeck 2003) under GTR+Gamma as the best-fitting model, for 10 million generations with parameter and topology sampling every 1000 generations and Markov Chain Monte Carlo (MCMC) diagnosis frequency of 100,000 and later discarded 25% of the first analysis as burn-in. For the likelihood analysis, we used RAxML version 8.2.10 (Stamatakis 2014) implementing the GTR+Gamma model with 1000 bootstrap replicates on the CIPRES Science Gateway platform (Miller *et al*. 2010). Genetic distances (uncorected *p-distance*) were estimated using MEGA 6.06 (Tamura *et al.* 2013). The two new sequences of *Cnemaspis* from Java were submitted to GenBank under the accession numbers MK161507 and MK161508.

TABLE 1. A list of the samples used in the molecular analyses with GenBank accession numbers. Abbreviated for voucher numbers are as follows: LSUHC, La Sierra University Herpetological Collection; AA, Rohan Pethiyagoda field series; AMB, Aaron M. Bauer field series; KUHE, Graduate School of Human and Environmental Studies, Kyoto University; KUZ, Zoological collection of Kyoto; MVZ, Museum of Vertebrate Zoology University of California, Berkeley; MZB, Museum Zoologicum Bogoriense, Indonesia; and WHT, Wildlife Heritage Trust, Sri Lanka.

Species	Vouchers	Locality	ND2 GenBank Accession
C. baueri	LSUHC 7274	Malaysia: Johor, Pulau Aur	KM024699
C. baueri	LSUHC 7303	Malaysia: Johor, Pulau Aur	KM024697
C. bidongensis	LSUHC 11444	Malaysia: Trenggani, Pulau Bidong	KM024703
C. bidongensis	LSUHC 11446	Malaysia: Trengganu, Pulau Bidong	KM024705
C. boulengeri	LSUHC 9278	Vietnam: Ca Mau Province, Con Dao Archipelago	KM024710
C. dringi	KUHE 56015	Malaysia: Serawak, Gunung Mulu	LC158337
C. grismeri	LSUHC 9970	Malaysia: Perak, Lenggong	KM024723
C. kallima	AA 82	Sri Lanka: Matale District, Rattota, Gammaduwa	KY037970
C. kandiana	AMB 7487	Sri Lanka, Kandy District, Gampola	KY037972
C. kendallii	LSUHC 5317	Indonesia: Riau Province, Pulau Serasan	KM024738
C. kendallii	LSUHC 9174	Malaysia: Sarawak, Gunung Gading	KM024742
C. kendallii	LSUHC 9179	Malaysia: Sarawak, Santubong	KM024744
C. kendallii	KUHE 57123	Malaysia: Serawak, Kuching	LC205718
C. kendallii	KUHE 57350	Malaysia: Serawak, Kuching	LC205720
C. kendallii	KUHE 57343	Malaysia: Serawak, Kuching	LC205719
C. kendallii	KUZ(JPN): R27060	Malaysia: Serawak, Kuching	LC158342
C. leucura	KUHE 57422	Malaysia: Serawak, Kuching	LC205724
C. leucura	KUHE 57423	Malaysia: Serawak, Kuching	LC205723
C. limi	LSUHC 3774	Malaysia: Pahang, Pulau Tioman	KM024749
C. limi	LSUHC 3888	Malaysia: Pahang, Pulau Tioman	KM024750
C. hangus	HC 0225	Malaysia: Pahang, Bukit Hangus	KM024729
C. mcguierei	LSUHC 8855	Malaysia: Perak, Bukit Larut	KM024753
C. mumpuniae	MZB Lace 10167	Indonesia: Pulau Natuna	KM024761
C. modiglianii	MVZ 239314	Indonesia: Pulau Enggano	KY037977
C. modiglianii	MVZ 239315	Indonesia: Pulau Enggano	KY037978
***C. muria* sp.nov.**	MZB Lace 14571	Indonesia: Java, Gunung Muria	MK161507
***C. muria* sp.nov.**	MZB Lace 14572	Indonesia: Java, Gunung Muria	MK161508
C. nigridia	KUZ(JPN): R27145	Malaysia: Serawak, Kuching, Lundu, Gunung Gading	LC158342
C. nigridia	LSUHC 9170	Malaysia: Serawak, Gunung Gading	KM024772
C. paripari	KUHE 57285	Malaysia: Serawak, Kuching	LC205725
C. paripari	LSUHC 9184	Malaysia: Serawak, Gua Paripari	KM024781
C. pava	AMB7494	Sri Lanka, Nuwara Eliya District, Labookellie	KY037980
C. peninsularis	LSUHC 5184	Malaysia: Johor, Pulau Seribuat	KM024796
C. peninsularis	LSUHC 5185	Malaysia: Johor, Pulau Seribuat	LSUHC 5185
C. peninsularis	LSUHC 53017	Malaysia: Johor, Pulau Aceh	
C. peninsularis	LSUHC 3773	Malaysia: Pahang, Pulau Tioman, Malaysia	KM024789
C. peninsularis	LSUHC 6381	Malaysia: Johor, Pulau Ibol	KM024801
C. pemanggilensis	LSUHC 80312	Malaysia: Johor, Pulau Pemanggil	KM024786
C. pemanggilensis	LSUHC 80313	Malaysia: Johor, Pulau Pemanggil	KM024787
C. pseudomcguirei	LSUHC 9146	Malaysia: Perak, Bukit Larut	KM024825
C. samanalensis	AMB7505	Sri Lanka: Nuwara Eliya District	KY037983
C. sundainsula	MZB Lace 10156	Indonesia: Riau Province, Pulau Natuna Besar, Ceruk Forest	KM024845
C. sundainsula	MZB Lace 10157	Indonesia: Riau Province, Pulau Natuna Besar, Ceruk Forest	KM024846
C. temiah	LSUHC 9160	Malaysia: Pahang, Cameron Highlands, Tanah Rata	KM024849
C. upendrai	WHT 7258	Sri Lanka, Nuwara Eliya District, Punduloya	KY037985

Results

Both ML and BI analysis yielded nearly the same phylogenetic tree topology, with only minor differences in the placement of species with low bootstrap values (Fig. 1). Peninsular Malaya, Bornean and Javan *Cnemaspis* formed a monophyletic group with strong support only from Bayesian posterior probabilities (BPP=100) but was not supported under Maximum Likelihood bootstraps. The new species from Java was placed with low support in the *C. kendalii* group but was strongly supported (1.00/100) as the sister taxon of *C. bidongensis* Grismer, Wood, Ahmad, Sumarli, Vazquez, Ismail, Nance, Mohd-amin, Othman, Rizaijessika, Kuss, Murdoch & Cobos, 2014 from Pulau Bidong in Peninsular Malaysia. The uncorrected *p-distance* between the new species and their congeners from Peninsular Malaysia, Borneo and their surrounding islands is large (range = 4.4–34.2 and while interspecies distances among *C. kendalii* group are quite high (range = 4.4–18.2%) (Table 2). The diagnostic characters revealed in the morphological analysis (Tables 4, 5) supported by the molecular results, support the distinctiveness of the Javan *Cnemaspis*, which is described below as a new species.

Systematics

***Cnemaspis muria* sp.nov.**
Muria Rock Gecko
Cicak Batu Gunung Muria
Figures 2–5
urn:lsid:zoobank.org:act:066FE9E7-7916-4E8E-AE81-CEFCCB8901C8

Holotype. MZB. Lace. 14571 (Fig. 2A), an adult male from the river bank at Gunung Muria, Kajar (village), Dawe (District), Kudus (Regency), Jawa Tengah (Province), Indonesia (06°39’47.4” S; 110°53’22.9” E; elevation 599 m asl), collected on 11 August 2018 by Awal Riyanto, Misbahul Munir, Rubby Alfian, Lianita Rarasandy and Rega D. Ganiarta.

Paratypes. MZB. Lace. 14564 (Fig. 2B), an adult female; MZB. Lace. 14565–70, six adult males from the same locality as holotype (06˚39’33.5” S; 110˚53’20.6” E; elevation 650 m asl), collected on 17 July 2018 by Andri I.S. Martamenggala, and MZB. Lace.14572 (Fig. 2C), an adult male, with the same data as holotype (6°39’36.9” S; 110°53’20.0” E; elevation 646 m asl).

Diagnosis. *Cnemaspis muria* **sp. nov.** differs from its congeners in Southeast Asian by the following combination characters: (1) maximum SVL of at least 58.1 mm in males and 56.9 mm in females, (2) a pair of sharpe conical tubercle clusters on occiput, (3) nuchal loop bearing a bridge of warts from the upper tympanum to the nape and made in a curved line, (4) dorsal tubercles not linearly arranged, (5) 18–20 paravertebral tubercles, (6) postmental separated by a single scale, (7) gular, pectoral, abdominal, subantebrachial, subbrachial, subfemoral, subtibial and subcaudal scales keeled, (8) no tubercles on lower flank, (9) both precloacal and femoral pores absent, (10) enlarged submetacarpal scales present at the base of first finger, (11) enlarged submetatarsal present at the base of first toe , (12) 38–40 ventral scales, (13) 31–35 lamellae under fourth toe, (14) two postcloacal tubercles on each side, (15) enlarged median subcaudal scale row present, (16) caudal tubercles encircling tail, (17) sexually dimorphic in color pattern: males with a yellow belly and the proximal subcaudal surfaces yellow becoming white distally, female with a white belly with proximal subcaudal surface of alternating white and black rings and black coloration distally.

Description of holotype. An adult male, 56.8 mm SVL; head oblong in dorsal profile, moderately large in size (HeadL/SVL 0.28), elongate (HeadW/HeadL 0.65), narrow and flattened (HeadD/HeadL 0.36), distinct from neck; snout short (SnoutL/HeadL 0.43), slightly concave in lateral profile; snout longer than the distance between eye and ear (SnouL/EarEye 1.67); canthus rostralis smoothly rounded; eye large (ED/HeadL 0.21; ED/SnoutL 0.50); pupil round; ear opening oval, taller than wide; rostral concave, dorsal 80% divided by longitudinal groove; rostral width 1.66 times of it’s length; rostral bordered posteriorly by two small supranasals and two large scales between the supranasals

TABLE 2. Uncorected *p-distance* (percent difference) based on 954 bp NADH dehydrogenase 2 gene sequences for representative *Cnemaspis kendalii* group. Ranges distance in parentheses.

No	Species	1	2	3	4	5	6	7	8
1	***Cnemaspis muria* sp. nov.**	0.0							
2	*Cnemaspis bidongensis*	4.4–4.5	0.1						
3	*Cnemaspis mumpuniae*	6.7	6.1–6.2	–					
4	*Cnemaspis peninsularis*	6.4–8.3	6.4–7.9	6.7–8.6	0.0–7.1				
5	*Cnemaspis baueri*	14.8–14.9	15.0–15.2	14.5–14.6	14.3–16.0	0.2			
6	*Cnemaspis pemanggilensis*	13.5–13.7	13.5–13.7	14.7–14.9	14.9–15.8	16.1–16.5	0.6		
7	*Cnemaspis kendalii*	17.4–17.7	17.3–17.6	18.0–18.4	17.5–18.8	18.2–19.0	18.7–19.6	0.2–1.8	
8	*Cnemaspis sundainsula*	18.1–18.2	16.7–16.9	17.4–17.5	17.5–18.7	19.5–19.7	18.3–18.6	17.3–18.0	0.1

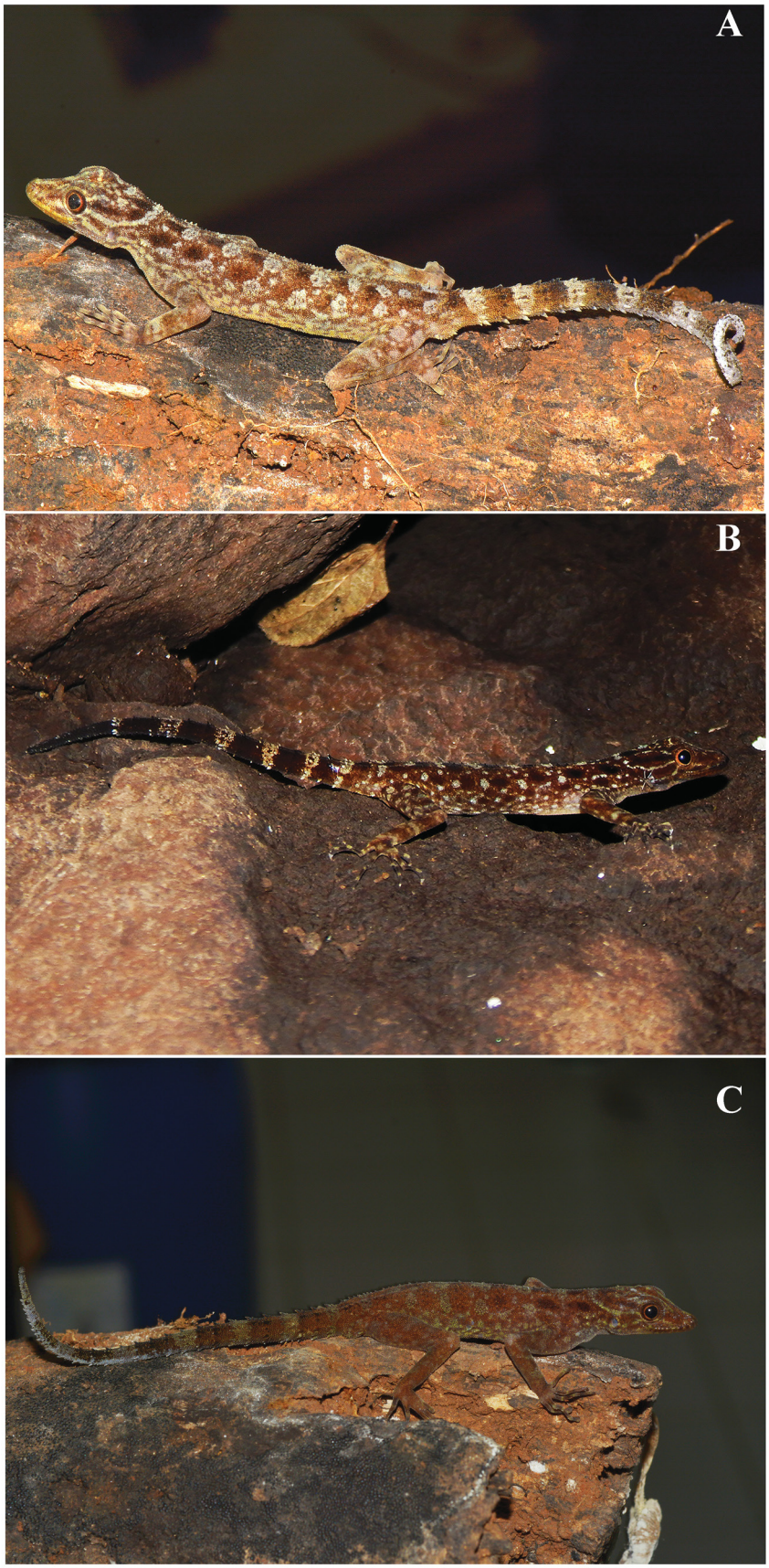

FIGURE 2. Types specimens of *Cnemaspis muria* **sp. nov**. A. Holotype (MZB.Lace.14571), male. B. Paratype (MZB. Lace.14564), female. C. Paratype (MZB.Lace.14572), male. Photos A and C by A. Riyanto, B by A. I. S. Martamenggala.

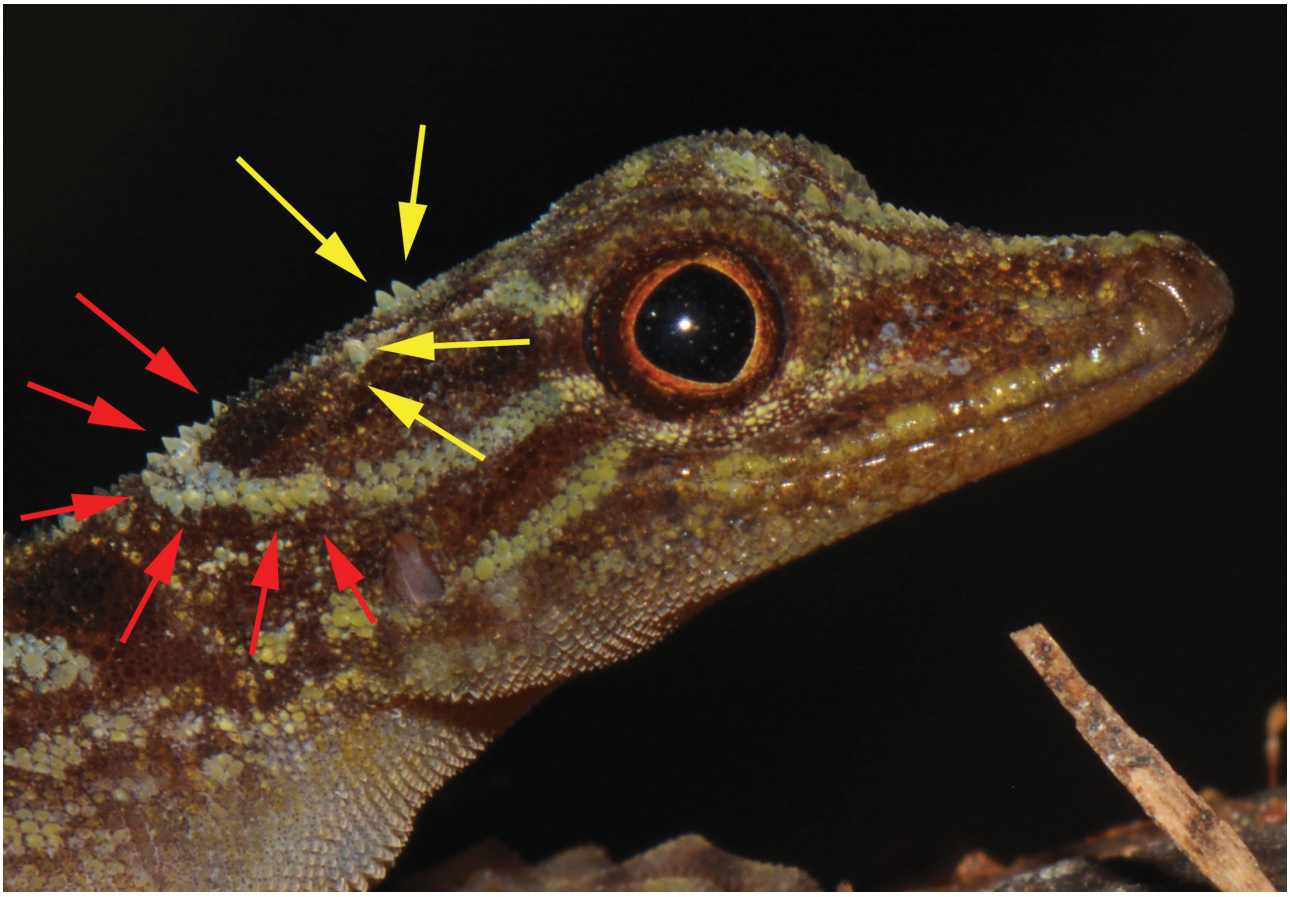

FIGURE 3. Close up of the head of *Cnemaspis muria* **sp. nov**. showing a pair of sharpe conical tubercles clustered on the occiput (yellow arrows) and nuchal loop bearing a bridge of warts in a curved line from the upper tympanum to the nape (red arrows). Photo by A. Riyanto.

and laterally by first supralabials; 10 supralabials on each side; 9 infralabials on each side, decreasing in size slightly posteriorly; nostrils elliptical, oriented posterodorsally, bordered posteriorly by small, granular, postnasal scales; a pair of bridges of warts present on occiput; nuchal loop present, bearing a bridge of warts extending from upper tympanum to the nape in a curved formation (Fig. 3).

Mental large, sub triangular, elongate (MentL/MentW 1.11), and extending posteriorly to a point equal to the anterior part of third infralabial, laterally in contact with first infralabial, posterolaterally bordered by three post-mental scales; asymmetric arrangement of the postmentals, slightly damaged on the right side of the postmental, postmentals bordered posteriorly by 11 weakly keeled scales; scales on throat raised and weakly keeled.

Body slender, elongate (AGL/SVL 0.41); dorsal body covered by pointed-weakly unicarinate scales which homogeneous in size; dorsal tubercles moderately prominent and randomly distributed; absent tubercles on flank; dorsal scales at mid-body smaller than ventral at same level; 20 PVT, flat, sub-pyramidal and weakly tricarinate, each about two or three times as large as granules separating them; abdominal and ventral scales sub-equal in size, ovoid, tricarinate, juxtaposed; pre-cloacal and femoral pores absent; enlarged femoral scales absent.

Forelimbs short (AntBraL/SVL 0.18; BracL/SVL 0.17); dorsal scales on both upper and lower arm, same size as abdominal scales; ventral scales on lower arm slightly larger than ventral scales on upper arm, unicarinate; ventral scales on lower arm weakly tricarinate; digits well developed, elongate, slender, all bearing slightly recurved claws; enlarged sub-metacarpal present at base of first finger (Fig. 4A); relative length of fingers 4>3>5>2>1.

Hindlimbs relatively long (TibiaL/SVL 0.26; ThighL/SVL 0.23); dorsal scales on both tibias and thighs weakly tricarinate, size relatively homogeneous; subtibial sligthly smaller than subfemoral scales, enlarged scales absent, both tricarinate; digits well developed, elongate, slender, all bearing slightly recurved claws; enlarged submetatarsal present at the base of first toe (Fig. 4B); relative length of toes 4>3>5>2>1; 31 lamellae under fourth toe.

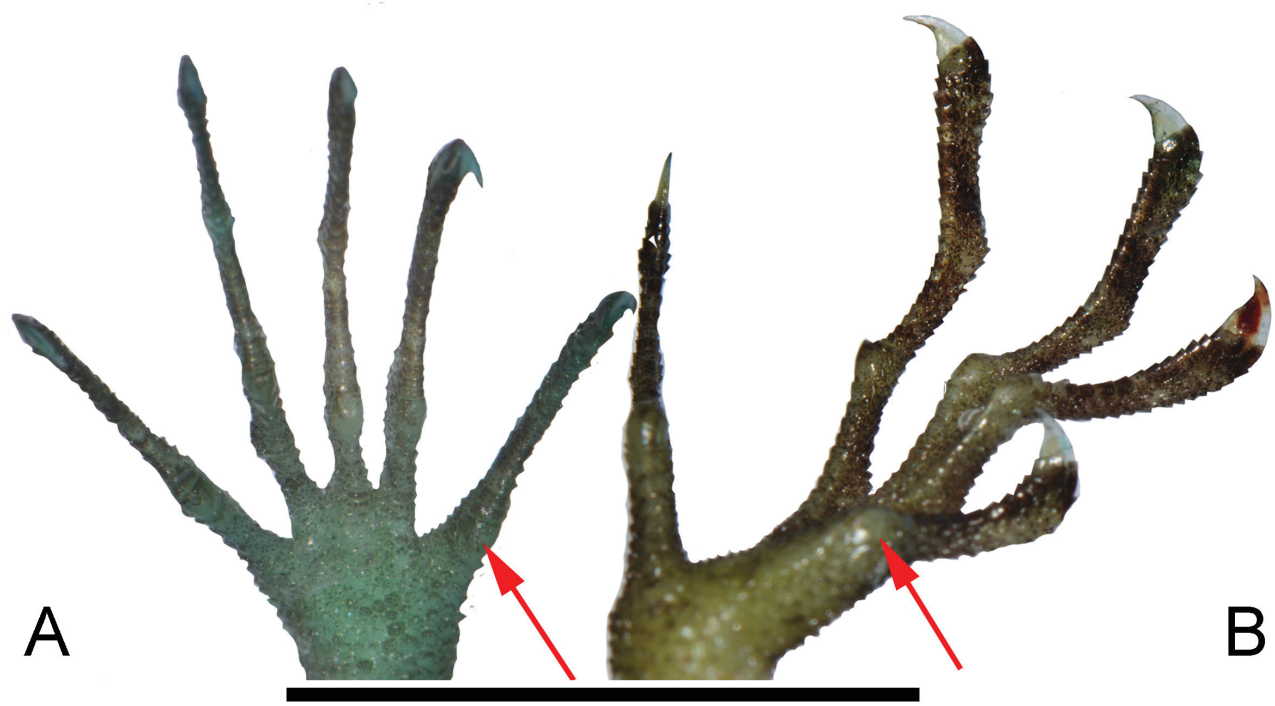

FIGURE 4. Palmar and tarsal views of the holotype *Cnemaspis muria* **sp. nov**. (MZB.Lace.14571), showing the enlarged metacarpal scale on the first finger (A) and the enlarged metatarsal scale on the first toe (B). Bar = 10 mm. Photos by A. Riyanto.

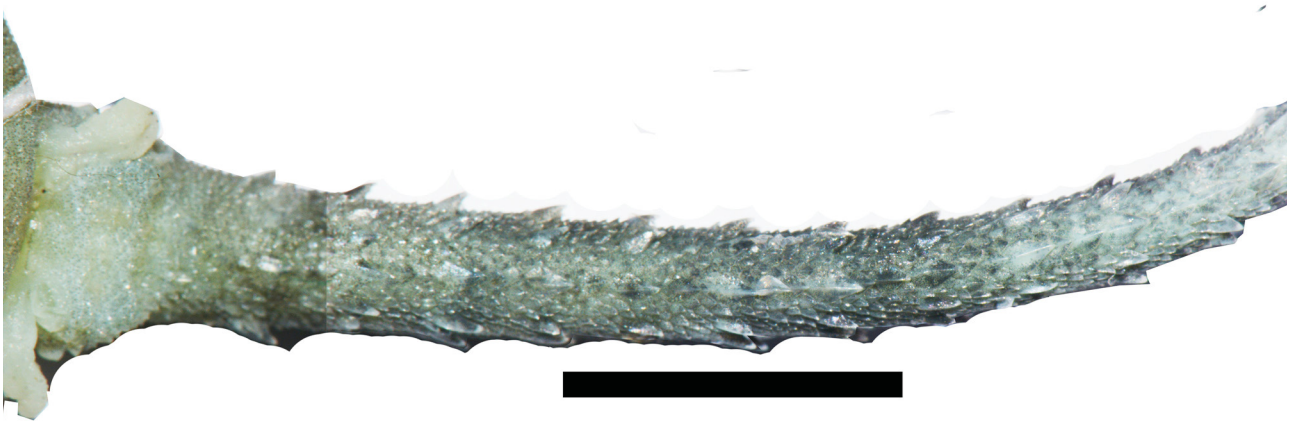

FIGURE 5. Ventral tail view of *Cnemaspis muria* **sp. nov**., holotype (MZB.Lace.14571) showing the unicarinate subcaudal scales, and the interrupted median row of enlarged unicarinate subcaudals. Bar = 10 mm. Photos by A. Riyanto.

Tail original (TailL 73.5 mm), long (TailL/SVL 1.29), base swollen; two conical postcloacal tubercles present on each side; a distinct furrow on the lateral surface of the tail present; caudal tubercles encircling tail in whorls; tail segmented with 21 whorls of tubercles, each whorl consisting of ten enlarged keeled tubercles separated from one another by 1 to 8 small scales; each whorl separated from adjacent whorls by 5 to 7 small scales; subcaudal scales unicarinate; interrupted median row of enlarged unicarinate subcaudals (Fig. 5).

Color pattern in life. Dorsal ground color brick-red; rostrum mixed yellowish; supralabials, infralabials and superciliaries yellow; a yellowish white continuous nuchal loop present, extending from middle posterior margin of one orbit to the other; a yellow line present, extending from lower posterior margin of orbits to the lower anterior margin of ears; white ocelli in shoulder region; three black weakly longitudinal spots arranged in a transverse row on the nape and shoulder region; seven blackish blotches intermixed with six white blotches along spine extending

from shoulder to hindlimb insertion; six white dorsolateral blotches between limb insertions; flanks bearing small, round, yellow spots that extend onto along lateral margins of abdomen; dorsal ground color of tail dorsum is brick-red, interrupted by blackish and white transverse bands and the apex of the tail white.

In mental region ventral part of infralabials yellow; gular region yellowish white; pectoral and abdominal regions yellow; subantebrachials, subbrachials, precloacal region, subtibials and subfemorals yellowish; palms and tarsals yellow; proximal subcaudals yellow until about the ninth whorl, then white distally.

Variation. Meristic data for the single female are similar to those of males and measural data are included within the range of males (*see* Table 3), which led us to consider them as conspecific, despite the differences in coloration. The new species exhibits sexual dimorphism in ventral color pattern. Males have a yellow belly whereas it is white in the female and the ventral surface of tail in males is proximally yellow and distally white (changing at approximately mid-length) but in the female alternating black and white rings completely encircle the tail, which is black distally (Fig. 6).

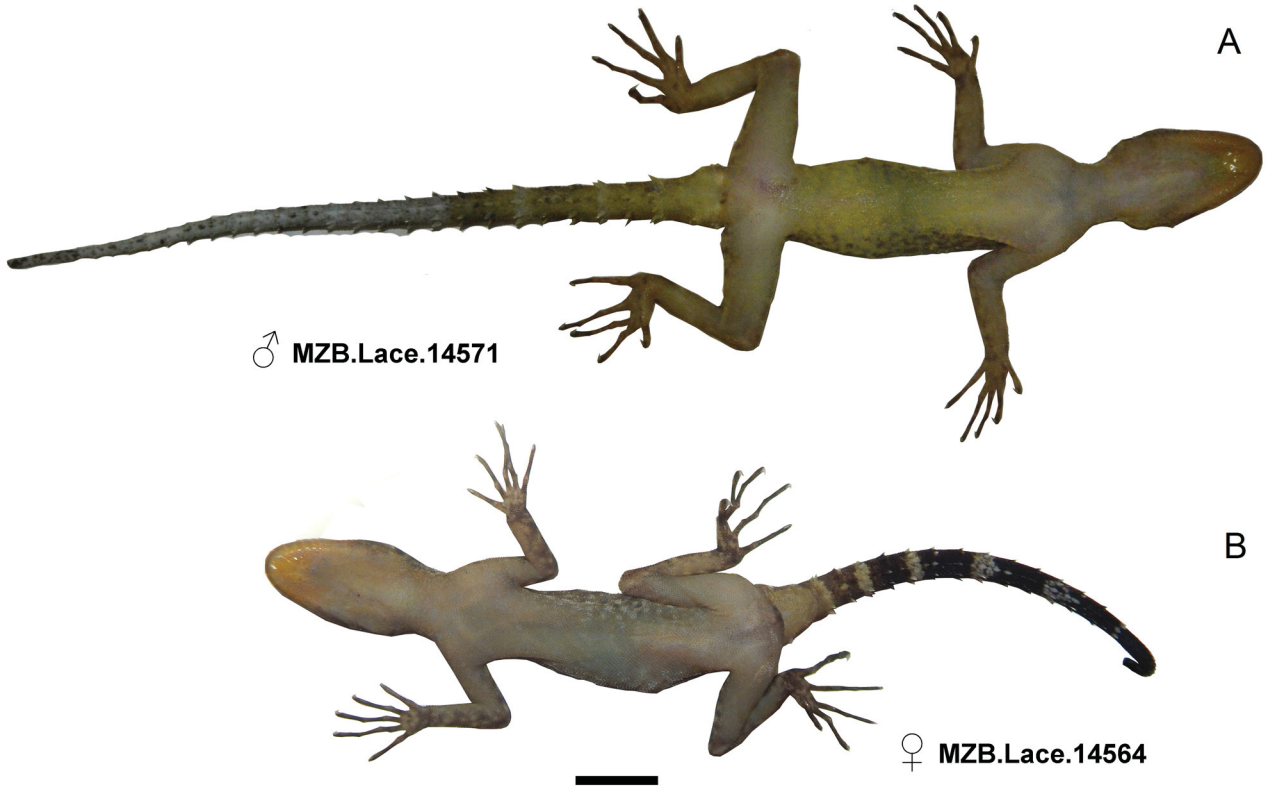

FIGURE 6. Sexual dimorphism exhibited in ventral views of *Cnemaspis muria* **sp. nov**. A. Male, holotype (MZB.Lace.14571), showing the subcaudal coloration that changes from yellow to white at about the midpoint of the tail. B. Female, paratype (MZB. Lace.14564), showing the subcaudal surface with alternating white and black bands and a black apex of the tail. Bar = 10 mm. Photo A by A. Riyanto, B by A. I. S. Martamenggala.

Etymology. The specific epithet *muria* is a noun in apposition and refers to Gunung Muria, the type locality of this species, and so far, the only known locality for the genus *Cnemaspis* in Java.

Distribution. *Cnemaspis muria* **sp. nov**. is only known from its type locality, in the southern foothills of Gunung Muria, a dormant volcano 1602 m in maximum elevation, located in the center of the Muria Peninsula of northern Central Java (Jawa Tengah). Gunung Muria represents the first, and so far, the only known locality for the genus *Cnemaspis* in Java (Fig. 7).

Natural history. *Cnemaspis muria* **sp. nov**. is a scansorial species known only from large granite rock microhabitats along rivers and coffee plantations (Fig. 8) on the southern slope of Gunung Muria at middle elevations, between 560 and 599 m. The holotype was caught at night, hanging on a tree root, 2 m above a dry river bank. The paratypes MZB. Lace. 14564 and MZB. Lace. 14572 were also caught at night, whereas the other paratypes were caught during the day hanging on shaded crevices of rocks. MZB. Lace. 14572 and four another specimens not collected were found foraging on rock walls, and sympatric with *Cyrtodactylus* sp.

TABLE 3. Meristic and mensural character states of the type series of *Cnemaspis muria* **sp. nov**. Meristic abbreviations are listed in the Materials and Methods. For SupL and InfL, the number in the parentheses is left side. TailL, the measurement for the original portion of the tail is in the parenthesis and the measurement for the regenerated portion is on the right. All measurements are in mm.

MZB.Lace, Field number	14571 holotype MUN263	14564 MVR006	14565 MVR007	14566 MVR008	14567 MVR009	14568 MVR010	14569 MVR011	14570 MVR012	14572 MUN364
Date collection	08/11/2018	07/17/2018	07/17/2018	07/17/2018	07/17/2018	07/17/2018	07/17/2018	07/17/2018	08/11/2018
Sex	Male	Female	Male	Male	Male	Male	Male	Male	Male
SupL	10 (10)	10 (11)	9 (10)	12 (13)	11 (12)	11 (11)	11 (12)	9 (10)	9 (9)
InfL	9 (9)	8 (9)	9 (8)	10 (10)	10 (10)	8 (8)	10 (8)	8 (10)	7 (7)
PVT	20	20	20	18	20	20	20	20	20
$LamT_4$	31	32	33	32	30	31	30	32	31
No. of postcloacal tubercles	2	2	2	2	2	2	2	2	2
Enlarged submetacarpal scale on 1st finger absent (0) or present (1)	1	1	1	1	1	1	1	1	1
Enlarged submetatarsal scale on 1st toe absent (0) or present (1)	1	1	1	1	1	1	1	1	1
Tubercles absent (0) or present (1) on lower flanks	0	0	0	0	0	0	0	0	0
Gular scales smooth (0) or keeled (1)	1	1	1	1	1	1	1	1	1
Pectoral scales smooth (0) or keeled (1)	1	1	1	1	1	1	1	1	1
Abdominal scales smooth (0) or keeled (1)	1	1	1	1	1	1	1	1	1
Subcaudal scales smooth (0) or keeled (1)	1	1	1	1	1	1	1	1	1
Enlarged median subcaudals absent (0) or present (1)	1	1	1	1	1	1	1	1	1
Single median row of enlarged subcaudals smooth (0) or keeled (1)	1	1	1	1	1	1	1	1	1
Tubercles encircling tail (1) or not (0)	1	1	1	1	1	1	1	1	1
SVL	56.8	56.9	57.3	57.4	58.0	58.6	58.5	58.1	56.4
TailL	73.5	54.1	69.1	76.2	66.9 (40.8)	72.8	68.3	59.9 (13.5)	73.0
AGL/SVL	0.41	0.43	0.41	0.44	0.45	0.43	0.43	0.43	0.43
HeadL/SVL	28.09	28.55	25.92	27.09	26.32	27.58	27.55	27.13	27.18
HeadW/HeadL	0.36	0.40	0.49	0.41	0.44	0.41	0.41	0.42	0.39
SnoutL/HeadL	0.43	0.41	0.45	0.41	0.43	0.44	0.41	0.44	0.42
SnoutL/EyeEar	1.67	1.48	1.52	1.49	1.29	1.67	1.54	1.42	1.52
SnoutL/OrbD	2.01	1.88	1.67	1.68	1.79	2.05	1.96	1.74	2.14
MentL/MentW	1.11	1.11	1.19	1.22	0.82	1.18	1.09	1.03	1.31
BracL/SVL	0.17	0.13	0.13	0.15	0.15	0.12	0.10	0.14	0.18
AntBraL/SVL	0.18	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.21
TibiaL/SVL	0.24	0.25	0.25	0.25	0.26	0.24	0.26	0.25	0.26
ThighL/SVL	0.23	0.22	0.22	0.19	0.21	0.20	0.20	0.28	0.23

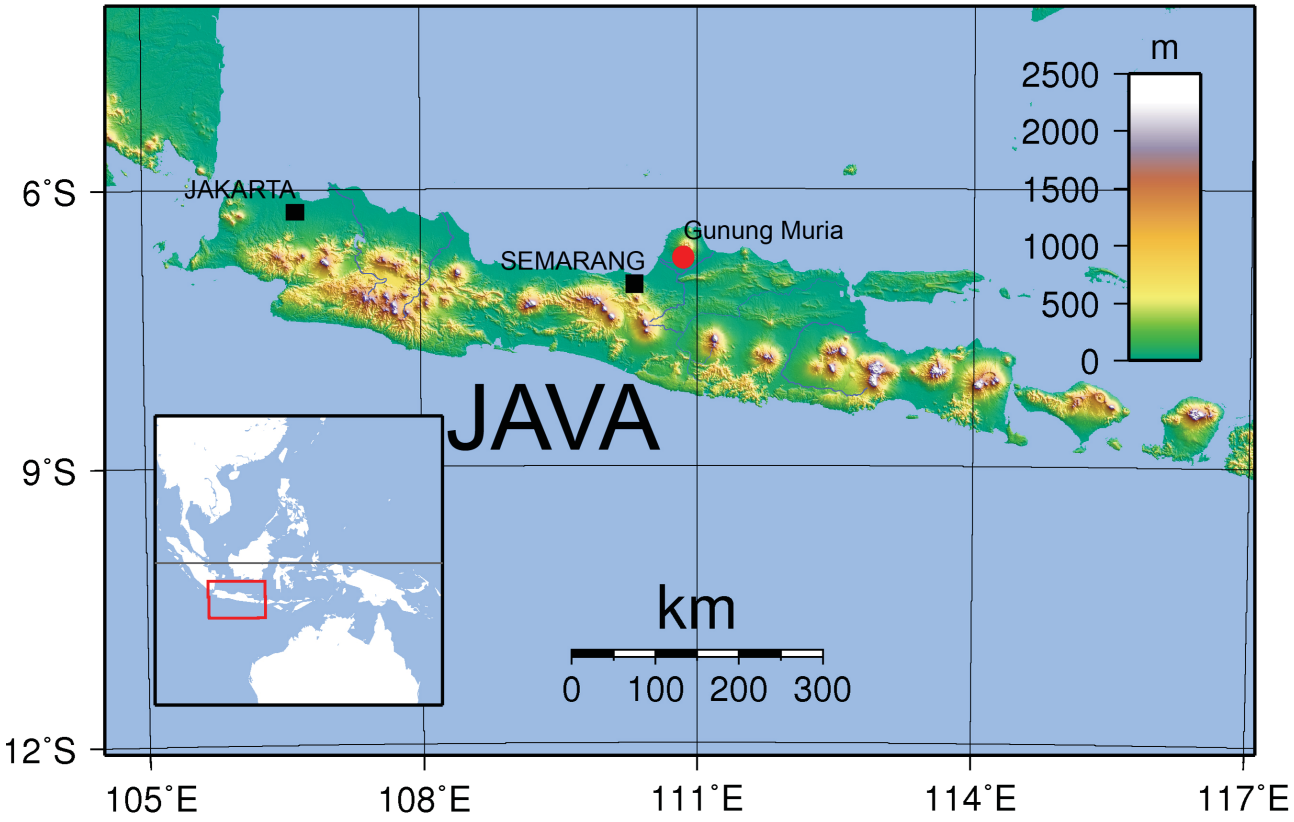

FIGURE 7. Map of Java, showing the position of Gunung Muria as the type locality of *Cnemaspis muria* **sp. nov**. (red circle). Base map modified from Wikipedia.

Comparison. *Cnemaspis muria* **sp. nov**. has numerous diagnostic characters states that separate it from congeners from the Malay Peninsula, adjacent small islands, Borneo, and Sumatra. Summary comparisons of the new species with other species of the Southern Sunda clade of the *C. kendalli* group are presented in Tables 4 and Table 5. The new species is easily distinguished from its sister taxon, *C. bidongensis*, by the presence of single median row of keeled subcaudals (*versus* smooth), an enlarged submetacarpal scales at the base of first finger (*versus* absence) and an enlarged submetatarsal scale at the base of first toe (*versus* absence); from *C. baueri* it is distinguished by the presence of an enlarged submetatarsal on the first toe (*versus* absence), absence of precloacal pores (*versus* presence), and presence of enlarged median row of subcaudals (*versus* absent); from *C. kendallii* it may be differentiated by the absence of tubercles on lower flank (*versus* presence), presence of enlarged submetatarsal scales on the first toe (*versus* absence), dorsal tubercles not linearly arranged (*versus* linearly arranged), ventral scales tricarinate (*versus* unicarinate) and single median row of keeled subcaudals (*versus* subcaudals not keeled); from *C. mumpuniae* by the absence (*versus* presence) of tubercles on the lower flank and presence (*versus* absence) of enlarged submetatarsal scales on the first toe; from *C. pemanggilensis* Grismer & Das, 2005, by a lower number of PVT (18–20 *versus* 30–37), presence of enlarged submetatarsal on the first toe (*versus* absence); from *C. peninsularis* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014 by the absence of tubercles on lower flank (*versus* presence), presence of single median row of keeled subcaudals (*versus* absence) and enlarged submetatarsal on the first toe (*versus* absence); and from *C. sundainsula* by absence of tubercles on lower flank (*versus* presence), tubercles arranged not linearly (*versus* linearly arranged), lower number of PVT (18–20 *versus* 26–37), presence of keeled subcaudal scales (*versus* smooth subcaudal scales), keeled enlarged median subcaudal row (*versus* smooth), and caudal tubercles encircling tail (*versus* not encircling).

TABLE 4. Diagnostic characters differentiating *Cnemaspis muria* **sp.nov.** from congeners of the *C. kendallii* complex (sensu Grismer *et al.* 2014) and *C. purnamai*. Abbreviations: w = weak; post = posterior.1 = maximum known SVL in mm, 2 = suplalabials, 3 = infralabials, 4 = number of paravertebral tubercles, 5 = dorsal tubercles linearly arranged (l) or random (0), 6 = tubercles on lower flanks absent (0) or present (1), 7 = subcaudal scales smooth (0) or keeled (1), 8 = single median row of subcaudals smooth (0) or keeled (1), 9 = caudal tubercles encircling tail (1) or not (0), 10 = enlarged median subcaudal row absent (0) or present (1), 11 = number of postcloacal tubercles (spur) in males, 12 = enlarged submetatarsal scale on 1st toe (1) or not, 13 = number lamella under 4th toes, References: A-this study, B–Amarasinghe *et al.* (2015), C–Grismer *et al.* (2014), and D–Riyanto *et al.* (2017).

Species	Characters													
	1	2	3	4	5	6	7	8	9	10	11	12	13	References
C. muria sp.nov.	58.6	9–13	7–10	18–20	0	0	1	1	1	1	2	1	31–35	A
C. baueri	67.4	11–13	8–12	18–27	0	w, 0	1	1	1	1	2	0	26–32	C
C. bidongensis	58.1	9, 10	7–9	21–26	0	0	1	0	1	1	1, 2	0	26–30	C
C. kendalli	58.4	10, 11	8, 9	18–26	w	w, 1	1	0	1	0	2	0	25–33	C
C. mumpuniae	60.9	9–12	8–11	18–25	w, 0	w, 1	1	0	1	1	1, 2	0	29–35	A, C
C. pemanggilensis	76.0	10–13	8–10	30–37	0	0, w	1	1	1	1	1, 2	0	27–34	C
C. peninsularis	60	10, 11	7–11	17–25	0	w, 1	1	0	1	0	1, 2	0	27–33	C
C. purnamai	54.1	9	8	14–15	0	0	1	1	1	1	2	1	22–24	A, D
C. rajabasa	58.7	13, 14	11, 12	20–21	0	0	1	1	1	0	2	0	28–34	B
C. sundagekko	68	11–13	8–11	20–25	0, w	0, w	1	0	1	0, post	2, 3	0	33–38	C
C. sundainsula	84.5	8–11	7–9	26–37	1	1	0	0	0	0	2–4	1	25–29	A, C

TABLE 5.—Comparison on color pattern of *Cnemaspis muria* **sp.nov**. and congeners of the *C. kendallii* complex (sensu Grismer *et al.* 2014) and *C. purnamai*. ? = data unavailable, and ♂ = characters present in males only.

	muria sp.nov.	*baurei*	*bidongensis*	*kendallii*	*mumpuniae*	*pemanggilensis*	*peninsularis*	*purnamai*	*rajabasa*	*sundagekko*	*sundainsula*
Dorsal color pattern sexually dimorphic	no	no	no	no	no	no	yes	no	no	no	no
Ventral pattern sexually dimorphic	yes	no	no	no	no	no	yes	?	no	no	yes
Thin, white, nuchal loop	yes	no	no	no	yes	no	no	yes	no	no	no
Black round spots on nape and anterior of body	no	yes	no	no	no	no	no	no	no	no	no
Dorsal ground color reddish	yes	no	no	no	yes	no	no	yes	no	no	no
Small, light, round spots on flanks	yes	no	no	no	yes	yes	no	yes	no	no	yes
Regenerated tail yellow	no	no	no	no	yes	no	yes	yes	no	no	no
Posterior portion of original tail black	yes	yes	no	no	yes	no	yes	?	no	no	no
Caudal bands present	yes	no	no	no	no	no	no	yes	no	no	no
Gular region orange	no	no	no	no	no	no	no	?	no	no	no
Gular region yellow	yes	no	no	no	no	no	no	?	no	no	yes
Throat orange	no	no	no	no	no	no	no	?	?	no	no
Throat yellow	yes	no	no	no	no	no	no	?	?	no	yes
Pectoral region orange	no	no	no	no	no	no	no	?	?	no	no
Pectoral region yellow	yes (♂)	no	no	no	no	no	no	?	?	no	no
Abdominen orange	no	no	no	no	no	no	no	?	?	no	no
Abdomen yellow	yes (♂)	no	no	no	no	no	no	?	?	no	yes
Ventral surface of forelimbs orange	no	no	no	no	no	no	no	?	?	no	no
Ventral surface of forelimbs yellow	yes (♂)	no	no	no	no	no	no	?	?	no	no
Ventral surface of hindlimbs orange	no	no	no	no	no	no	no	?	?	no	no
Ventral surface of hindlimbs yellow	yes (♂)	no	no	no	no	no	no	?	?	no	no
Subcaudal orange	no	no	no	no	no	no	no	?	?	no	no
Subcaudal yellow	yes (♂)	no	no	no	no	no	no	?	?	no	yes
At least posterior half of subcaudal region white	yes (♂)	no	no	yes	no	no	no	?	?	no	yes

FIGURE 8. The habitat type of *Cnemaspis muria* **sp. nov**. in Kajar village, Dawe District, Kudus Regency in Gunung Muria. (A) Large rocks in a small river and (B) Large rock in a coffee plantation. Photos by A. I. S. Martamenggala.

Cnemaspis muria **sp. nov**. may be easily distinguished from *C. purnamai* Riyanto, Hamidy, Sidik & Gunalen, 2017, newly described from Belitung Island, by the presence of the nuchal loop bearing a bridge of warts extending from upper tympanum to the nape in a curved line (*versus* this configuration lacking) and a greater number of lamellae under the fourth toe (31–35 *versus* 22–24); and from *C. rajabasa* by the presence of an enlarged median subcaudal row (*versus* median row not enlarged) and enlarged submetatarsal under first toe (*versus* lacks enlarged submetatarsal under first toe); and from *C. sundagekko* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014, by the presence of single median row of enlarged keeled subcaudals (*versus* median row not enlarged), and an enlarged submetatarsal scale on the first toe (*versus* absent).

The ventral scales in the new species are keeled, whereas the following species have smooth ventral scales: *Cnemaspis andalas, C. biocellata* Grismer, Chan, Nurolhuda & Sumontha, 2008*, C. flavigaster* Chan & Grismer, 2008*, C. kumpoli* Taylor, 1963*, C. monachorum* Grismer, Ahmad, Chan, Belabut, Muin, Wood & Ahmad, 2009*, C. minang*, and *C. tapanuli.*

The lack of precloacal pores in the new species distinguish it from all the following species which have precloacal pores: *C. andalas*, *C. affinis* (Stoliczka, 1870), *C. argus* Dring, 1979, *C. bayuensis* Grismer, Grismer, Wood & Chan, 2008, *C. bidongensis*, *C. biocellata, C. hangus* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014, *C. flavigaster*, *C. dezwani*, *C. dringi, C. flavolineata* (Nicholls, 1949), *C. gismeri* Wood, Quah, Anuar & Muin, 2013, *C. harimau* Chan, Grismer, Shahrul, Quah, Muin, Savage, Grismer, Ahmad, Remegio & Greer, 2010, *C. karsticola* Grismer, Grismer, Wood & Chan, 2008, *C. kumpoli*, *C. leucura*, *C. limi* Das & Grismer, 2003, *C. minang*, *C. mcguirei* Grismer, Grismer, Wood & Chan, 2008, *C. modiglianii*, *C. monochorum, C. narathiwatensis* Grismer, Sumontha, Cota, Grismer, Wood, Pauwels & Kunya, 2010, *C. nigrida, C. pagai*, *C. paripari C. perhentianensis* Grismer & Chan, 2008, *C. pseudomcguirei* Grismer, Ahmad, Chan, Belabut, Muin, Wood & Ahmad, 2009, *C. selamatkanmerapoh* Grismer, Wood, Mohamed, Chan, Heinz, Sumarli, Chan & Loredo, 2013, *C. stongensis* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014, *C. tapanuli*, *C. temiah* Grismer, Wood, Anuar, Riyanto, Ahmad, Muin, Sumontha, Grismer, Chan, Quah & Pauwels, 2014 and *C. whittenorum.*

Cnemaspis muria **sp. nov**. possesses enlarged submetatarsal scales on the first toe which distinguishes it from all the following species which lack this character: *C. affinis, C. argus C. bayuensis, C. biocellata, C. flavolineata, C. grismeri*, *C. hangus, C. harimau, C. karsticola, C. limi, C. mashuriae, C. mcguirei, C. narathiwatensis, C. pemanggilensis, C. perhentianensis, C. selamatkanmerapoh, C. shahruli* Grismer, Chan, Quah, Mohd, Savage, Grismer, Ahmad, Greer & Remegio, 2010*, C. stongensis, C. tapanuli,* and *C. temiah.*

The new species possesses caudal tubercles encircling the tail which differentiates it from *Cnemaspis affinis, C. andalas, C. argus, C. bayuensis, C. biocellata, C. dringi, C. flavigaster, C. leucura, C. grismeri, C. hangus, C. karsticola, C. kumpoli, C. laoensis, C. limi, C. mahsuriae* Grismer, Wood, Quah, Anuar, Ngadi & Ahmad, 2015, *C. minang, C. mcguirei, C. monachorum, C. narathiwatensis, C. nigridia, C. pagai, C. paripari, C. perhentianensis, C. pseudomcguirei, C. roticanai* Grismer & Chan, 2010*, C. selamatkanmerapoh, C. sundainsula, C. shahruli, C. stongensis, C. tapanuli,* and *C. temiah*.

In having enlarged median row of subcaudals, *Cnemaspis muria* **sp. nov**. can be distinguished from *C. aceh, C. andalas, C. bidongensis, C. biocellata, C. bidongensis, C. dezwaani, C. jacobsoni, C. kumpoli, C. limi, C. mahsuriae, C. minang, C. modiglianii, C. monachorum, C. mumpuniae, C. nigridia, C. pagai, C. paripari, C. pemanggilensis, C. sundagekko, C. sundainsula, C. whittenorum,* and *C. tapanuli.*

The new species can be separated from *Cnemaspis andalas, C. biocellata, C. flavigaster, C. kumpoli, C. laoensis, C. limi, C. minang, C. monachorum, C. sundainsula,* and *C. tapanuli* by having keeled subcaudal scales.

The new species lacks a vertebral stripe which separates it from *C. aceh, C. andalas, C. dezwaani, C. flavolineata*, C. jacobsoni, C. narathiwatensis, C. pseudomcguirei*, C. shahruli*, C. tapanuli, C. temiah** and *C. whittenorum* (species with variable presence of this character indicated by an asterisk *).

Discussion

The discovery of *Cnemaspis muria* **sp. nov**. on the island of Java is biogeographically significant, since the occurrence of this genus was unexpected for the island. The southernmost and closest known species in distribution is *C. rajabasa,* from Lampung, Sumatra. Gunung Muria is separated from Sumatera by ~ 580 km, Kalimantan by ~350

km, and Belitung Island (the type locality of *C. purnamai*) by ~470 km. The African-Asian Frog genus *Chiromantis* also occurs in Java (Riyanto & Kurniati 2014; Wostl *et al.* 2017), as do other recently described reptiles and amphibians (Riyanto *et al.* 2014; Riyanto *et al.* 2015; Hartmann *et al.* 2016; Kieckbusch *et al.* 2016; Wostl *et al.* 2017; Hamidy *et al.* 2018). These novelties have shown Java to be a more herpetologically interesting place than heretofore believed, even though it was believed to have been relatively well studied during the long history of exploration during the Dutch colonial period.

The new species was found active in rock microhabitats along rivers and in coffee plantations. With little ecological data we may assume that *Cnemaspis muria* **sp. nov**. participates in controlling insect populations, including pests on coffee plants. As such there are conservation implications for this species. The use of herbicides and insecticides in coffee plantations should be limited, and only applied where there is a serious pest problem. An integrated pest control management approach should take into account the role of the new species, and that of other lizards, as natural pest control agents, and not put their existence in jeopardy.

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APPENDIX 1. Spesimens examined.

Cnemaspis aceh: MZB.Lace.12998 (holotype); *C. Andalas*: MZB.Lace.12999 (holotype), 13000 (paratype); *C. minang*: MZB. Lace.13002 (holotype), 13002 (paratype); *C. mumpuniae.* MZB.Lace.10167 (holotype); *C. muria*: MZB.Lace.14564–70, 14572 (paratypes), 14571 (holotye); C. *pagai*: MZB.Lace.13004 (holotype); *C. purnamai*: MZB.Lace.14074–75 (paratypes), 14076 (holotype); C. *rajabasa*: MZB.Lace.6595 (holotype); *C. sundainsula*: MZB.Lace.9438 (holotype); MZB.Lace.2240 (holotype).